Further considerations on issues impacting the resultant measured spectrum of magnetron based Radar systems.

Background

This document is intended to highlight factors that can severely influence the measured spectrum profile of a magnetron based Radar, it will address issues that currently not covered by ITU-R M1177 with the applicability to both direct and indirect methods.
The collected results and observations in this document are based on lessons learned from an extensive measurement exercise on spurious emissions for a number of X band Radars. The factors noted here are recognised as not being the only additional set to consider and it is most likely that other issues could rise to the surface as further research and study is applied to the subject of Radar spurious spectrum measurement. The aim here is to provide additional data on the behaviour of Radar systems under spurious measurements method as oppose to the true behaviour of the Radar system under normal operation.

Key Issues

The issue in extreme simplicity is centred around the fact the load characteristics of a Radar system has a major influence on the resultant radar output spectrum including the output pulse characteristics, shape and profile. In principle the whole system can be summarised down to a signal source, transmission path impedance and load impedance all of which will determine the shape and value of the output waveform.

An expansion on that would lead us to consider many key issues, some of those are the VSWR and the phase values AS SEEN BY THE SOURCE (magnetron in this case) in a given system.

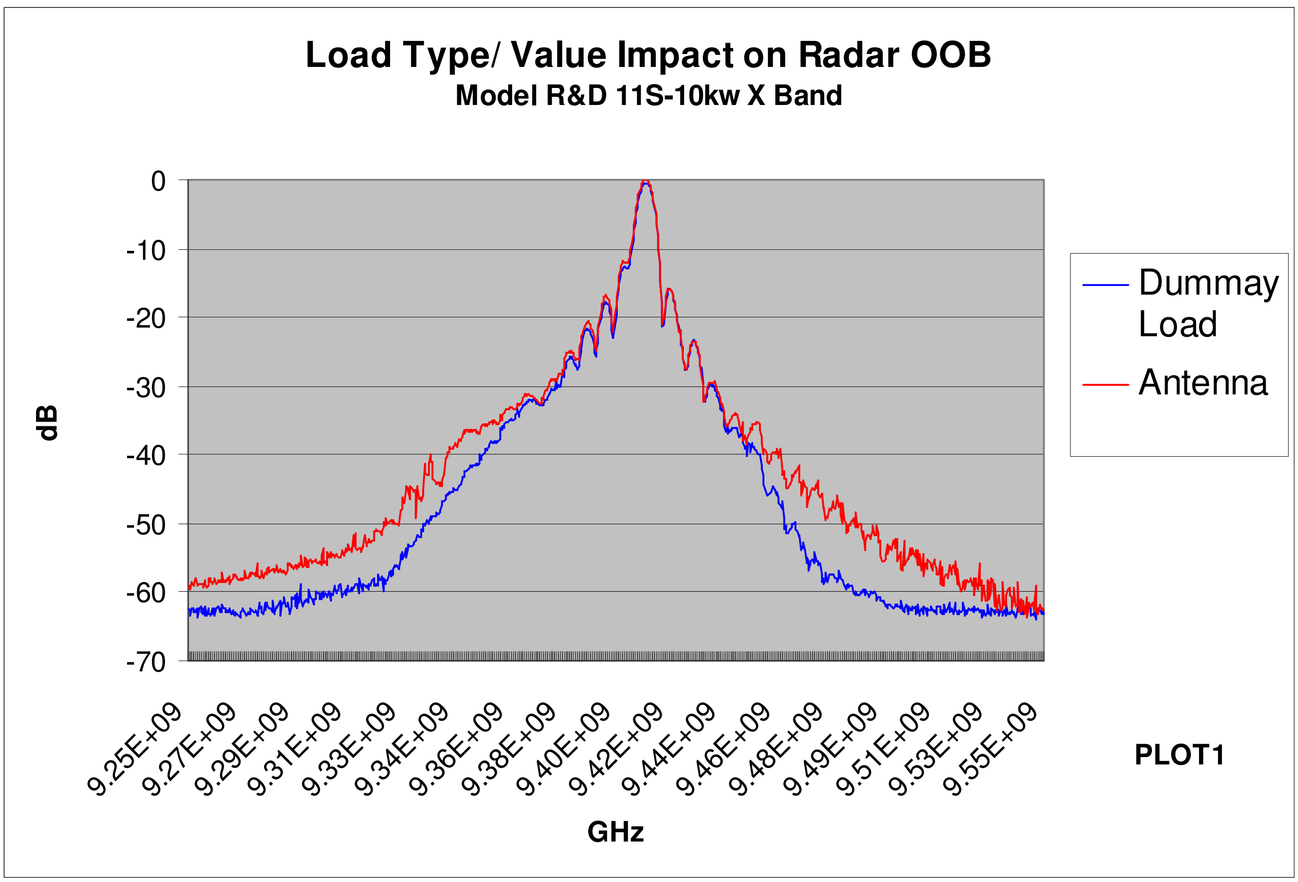
For a given Radar system the microwave path /structure (“ plumbing”) and the antenna with its associated mechanical arrangements would be the “corner stones” that would define transmission loss, match, VSWR and phase values however what is not true is the assumption that all of those are constants throughout the normal operation of the Radar. Further more would be the issue of changes in some of magnetron characteristics as a direct resultant to the DYANAMIC change in the stated system physical parameters.

This document will focus on some of the issues impacting VSWR, load and system phase value change due to either method of measurements and or physical nature of the Radar design. This would be narrowed down to:

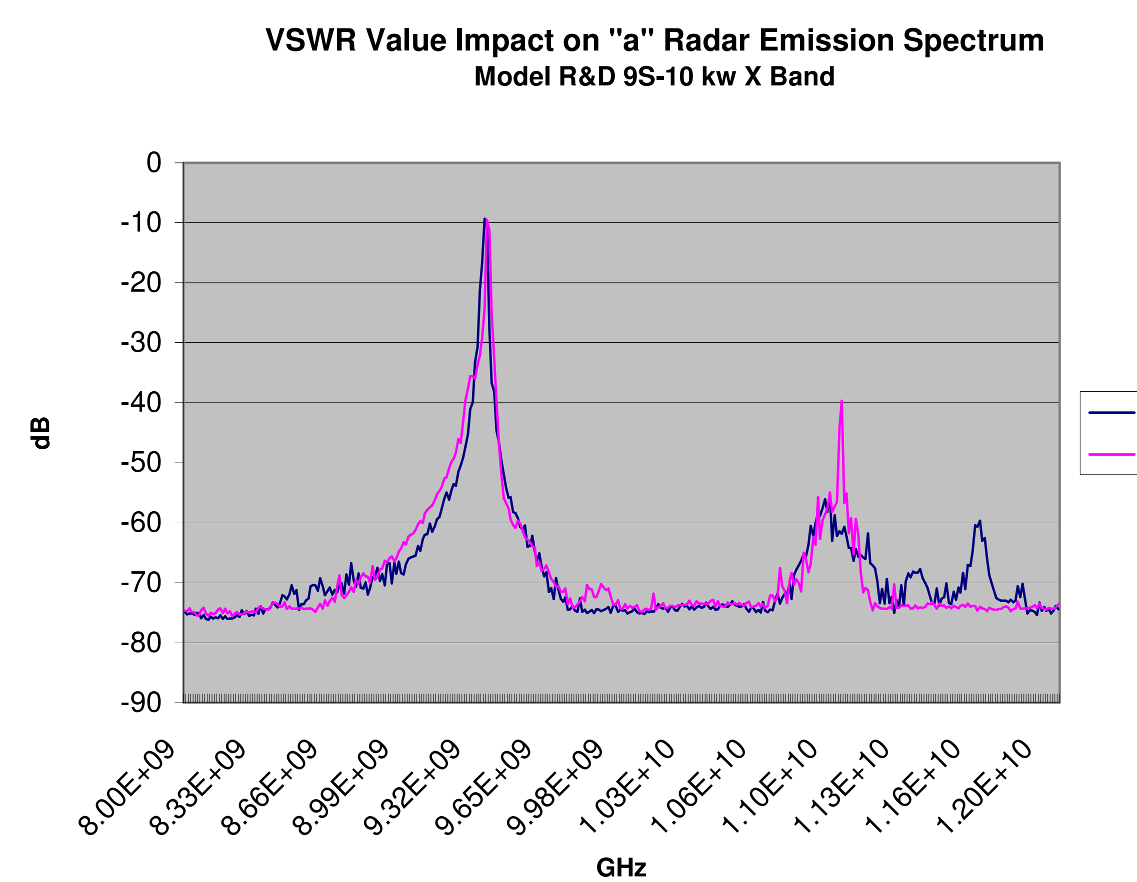
1- Load characteristics change impact due to use of dummy load.
2- VSWR Change Impact with Rotary Joint movement.
3- Phase change Impact as a direct result of output feed change.
   (Done by the coupling of the rotary joint to a measuring system in the indirect method)

PLOT1 reflects the error in the B-40 measured value when a pure dummay load replaces the actual antenna on the test unit. An extensive investigation into this

indicated that the actual cause of that was primarily dependent on the change in the reflected component to the magnetron back from the load (so in a case of a resistive load that would be zero for a VSWR of 1:1). That was Easley established by the introduction of extremely high isolation stage between the magnetron and the rest of the system at main mode (to a value of better then 38 dB). It is important to note here that almost all commercial radars don't have an isolator at main mode between the magnetron and the microwave circuit (plumbing). For those Radars that deploy special filters for a particular purpose (aperture control for dual frequency pulse Radars) it was found that an isolator stage was provided between the magnetron and the plumbing providing isolation no better than 21 dB further more standard isolator blocks on the market by leading microwave manufactures was in the range of 18 to 23 dB. It was not possible at all to predict this error in the B-40 value from consideration to the antenna parameters alone since it was in effect a parameter of the S21 and S22 value of the antenna match as viewed from the microwave circuit end.
For the Radar used the error shown in PLOT1 has amounted to a value of 15% in the B-40.



The next point is the VSWR change caused by the actual rotation of the rotary joint, in both specified direct and indirect methods the rotary joint is stationary and thus its effective contribution to the total VSWR value of the system seen by the magnetron is fixed. It is important to note here that this finding did not consider the effect on the spectrum due to the dynamic change of the VSWR (as the rotary joint is rotating under normal operation) but consideration was made to the total change in the VSWR between two fixed positions of the rotary joint (worst and best values) and the results is reflected in PLOT2. It is important to note from PLOT2 that this effect extend beyond the main mode (see later). It is important to note here that the problem highlighted in PLOT2 are obviously dependent on the design of the rotary joint in the Radar under test and will vary in value dependent on the quality and the design of the rotary joint however it is important to state that the value observed is typical and was substantiated by conducting the same check on other brands of commercial radars.



PLOT2

The above data has focused on a particular effect of an individual element for a specific region in the Radar spectrum and it is thus important to note here that the combined effect of more than one factor change (VSWR, LOAD and PHASE) at any given time would obviously render the measured spectrum with even more errors that are more complex to decipher with single analysis. In order to demonstrate the latter statement this report would take another point on the total spectrum and observe the effect of a combined VSWR and PHASE change at the same time, this new selected point is the 2nd harmonic of the fundamental and in X band would be around 18.8GHz.

IMAGE1 is a measurement of 2nd Harmonic of the same X band Radar used in PLOT2, the lower amplitude trace of the two shown relating to a VSWR of 1.32 and the higher trace for a VSWR of 1.58 for a fixed phase value in the system. The delta in amplitude is approximately 13 dB.

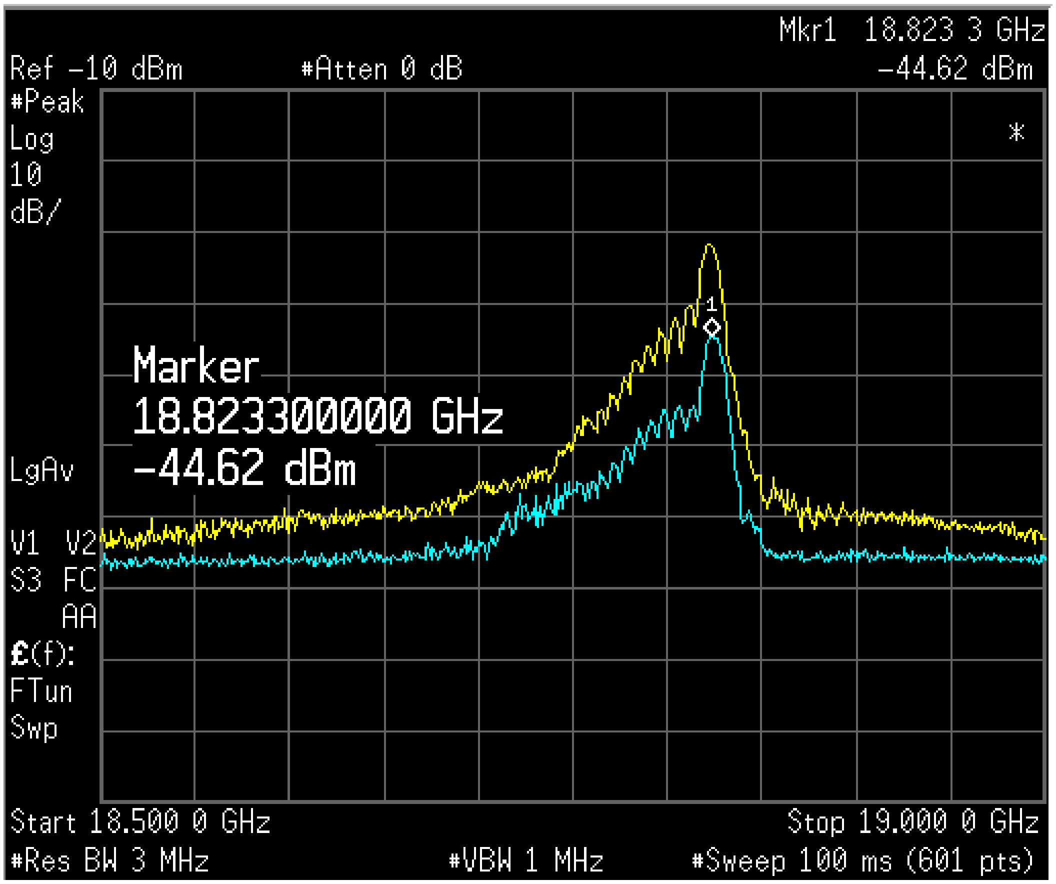


IMAGE1

The last experiment was repeated on a patch array antenna type Radar and a similar result was achieved as shown in IMAGE2. The lower of the two traces is corresponding to a VSWR of 1.42 and the higher of the two traces corresponding to a VSWR of 1.64 and a fixed value phase defined by the microwave circuit in the standard configuration of the Radar under test (production standard). The delta between the two traces is approximately 10dB.

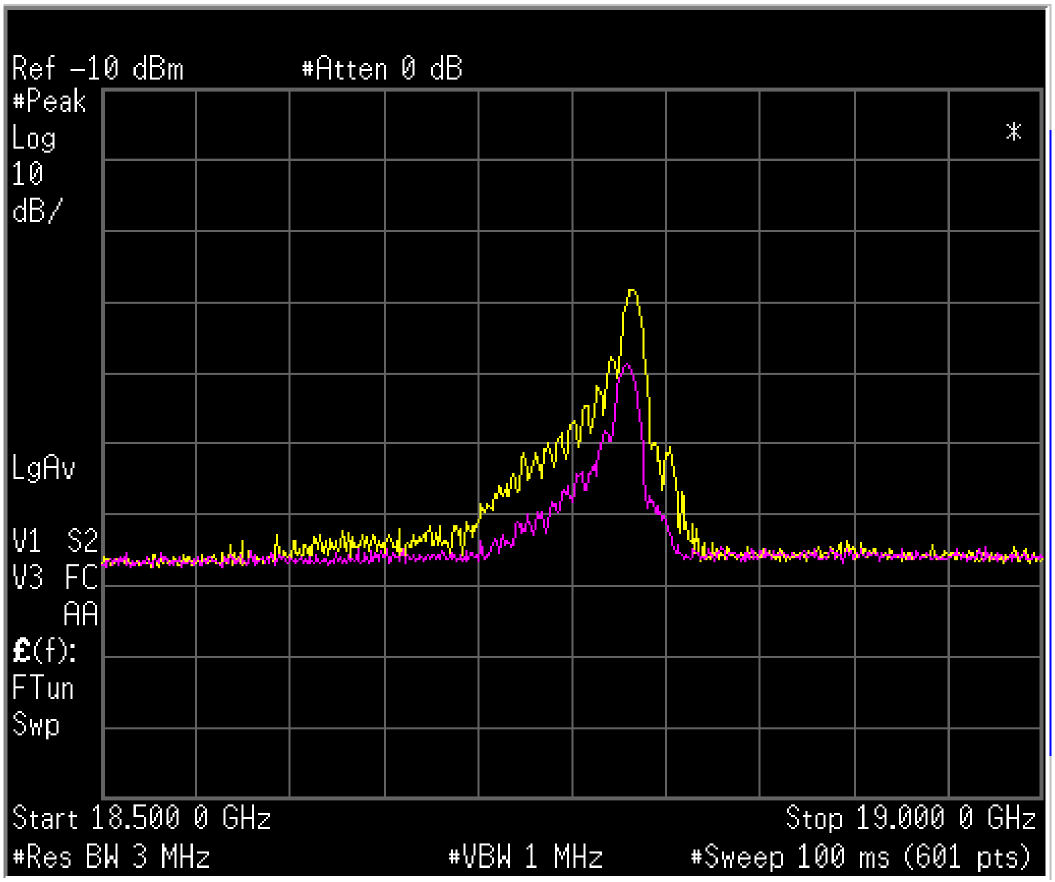


IMAGE2

The same Radar now used in IMAGE2 has an altered phase value of +9 mm and the measurement was repeated on the value of the 2nd harmonic frequency for VSWR 1.42 and 1.64 respectively, the data are now shown in IMAGE3. The lower amplitude trace in IMAGE3 corresponds to a VSWR of 1.42 and the higher trace corresponds to a VSWR of 1.64. It is important to note here that the delta and relative amplitude for the frequency under consideration has changed between IMAGE2 and 3 for the same Radar and the same VSWR values, further more one should also note the slight change in frequency between the two sets, the latter is due to alteration of the pushing effect on the magnetron due to the combined change.

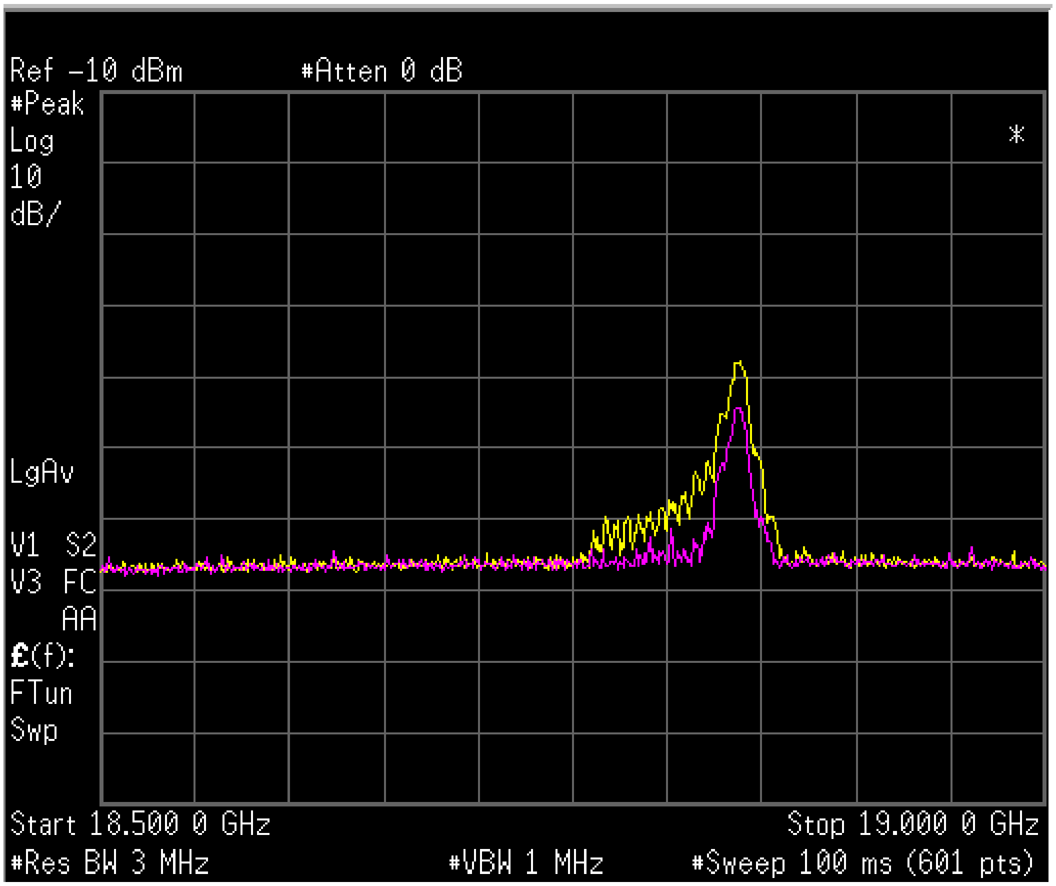


IMAGE3

Summary

The issues highlighted above can produce considerable error in various parts of the measured Radar spectrum. The error level and severity is totally dependent on the nature and type of magnetron, microwave circuit design and construction from physical point of view and the type of antenna in use.

Method of measurements for spurious Radar emission need to be so that it will ensure that physical test condition and setup of the unit under test would not introduce errors or alter the fundamental parameters that produce and control the resultant spectrum.

There are other factors in a magnetron based Radar system that can seriously worsen the observations made in this document like temperature and the pushing characteristics of the magnetron in use, the combinations of all factors will produce a more complex error in the final picture in particular at extreme operating temperature conditions, the latter is more of a serious problem for low power Radars were the rise in temperature due to operation is small compared to high power Radar system.

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